Municipal Solid Waste Landfill Guidelines

NOVA SCOTIA
Environment and Labour

Approval Date: October 24, 1997 Effective Date: October 24, 1997

Approved By: Peter Underwood

Version Control: Replaces all documents heretofore prepared and/or issued by the Department respecting the construction and operation of municipal solid waste landfills, including, but not limited to the draft "Nova Scotia. Standards and Guidelines Manual for Landfills" (July 1994)

Latest revision - November 10, 2004 (administrative amendments).

I. GENERAL

1. Purpose

(a) The purpose of these guidelines is to provide guidance for the proper environmental management and disposal of municipal solid waste. Extensions or modifications for existing operations are dealt with on a case by case basis. Site specific siting criteria is the responsibility of the proponent.

(b) These guidelines also provide guidance as to the requirements to obtain an approval to construct and operate a municipal solid waste landfill.

(c) Refer to Schedule "A" for the definition of terms used in these guidelines.

(d) Final assessment of applications for the construction and operation of a landfill will be made on a case by case basis. For further information respecting these guidelines, contact the Nova Scotia Environment and Labour Regional/District office where the landfill is located.

2. Applicable Documentation

Applicable documentation to which these guidelines apply include, but is not limited to, the following:

- *Environment Act*, S.N.S. 1994-95, c.1, Part IX
- Solid Waste-Resource Management Strategy (1995)
- *Solid Waste-Resource Management Regulations*
- *Activities Designation Regulations*
- *Approvals Procedure Regulations*
- Pit and Quarry Guidelines (May 1999)
- Guidelines for Disposal of Contaminated Solids in Landfills (March 22, 1994)
- Contingency Plan Criteria for Releases of Dangerous Goods and Hazardous Materials (March 26, 1990)

3. Applicability

(a) These guidelines apply to any land which is intended to be a landfill for the disposal of municipal solid waste.

(b) No person shall own, construct, manage, operate, alter or modify a landfill without obtaining approval from the Minister.

II. APPLICATION FOR APPROVALS

1. Application

(a) Prior to construction of a landfill, an approval must be obtained from the Department pursuant to Section 31 (1) of the Nova Scotia *Solid Waste-Resource Management Regulations.*

(b) Applications for an approval to construct and/or operate a landfill must be accompanied by a report detailing items described in each of the following sections of these guidelines and other supporting documentation, as may be requested by the Department.

(c) Unless specifically exempted by the Administrator, the applicant is to provide all information necessary to satisfy the requirements of each of the following sections.

III. LANDFILL DESIGN AND CONSTRUCTION

1. Minimum Standards

(a) The following sections outline the minimum standards that should be incorporated in the design and construction of the landfill. All of the components of the landfill should be designed to function over the lifespan of the facility. All of the systems and features to be incorporated in the construction of the landfill should be of a demonstrable technology. Alternates to the landfill components described in these guidelines may be employed provided that they are based on newer technologies and/or on changing waste characteristics.

(b) In the event that a proponent advocates an alternative design to the minimum standard, it will be the responsibility of the proponent to demonstrate to the satisfaction of the Department that the proposed alternate design is capable of achieving an equivalent or higher level of protection than the minimum standards. Any proposal for an alternate design will be assessed on the technical merits of the design and will be evaluated on a case by case basis.

2. General Landfill Requirements

All landfills should be designed to incorporate the following components:

- landfill liner system
- landfill final cover system
- leachate management system
- landfill gas management system
- surface water management system
- groundwater management system
- disposal material monitoring
- separation distances
- quality control/assurance

3. Landfill Liner System

(a) General Requirements

All landfill liners shall consist of the following components (see Figure 1 for a typical cross-section of a landfill liner system):

- subbase
- base
- bottom liner and leak detection system
- soil liner component
- flexible membrane liner
- leachate collection layer
- cushion layer

(b) Subbase

The subbase of the landfill liner system is the lowest point of the excavated area upon which the liner system is to be placed. The subbase will be an in-situ material of sufficient bearing capacity to support the material to be placed above it during the lifespan of the facility. Material encountered in the subbase which does not meet the required bearing capacity shall be excavated and replaced with appropriate structural fill material.

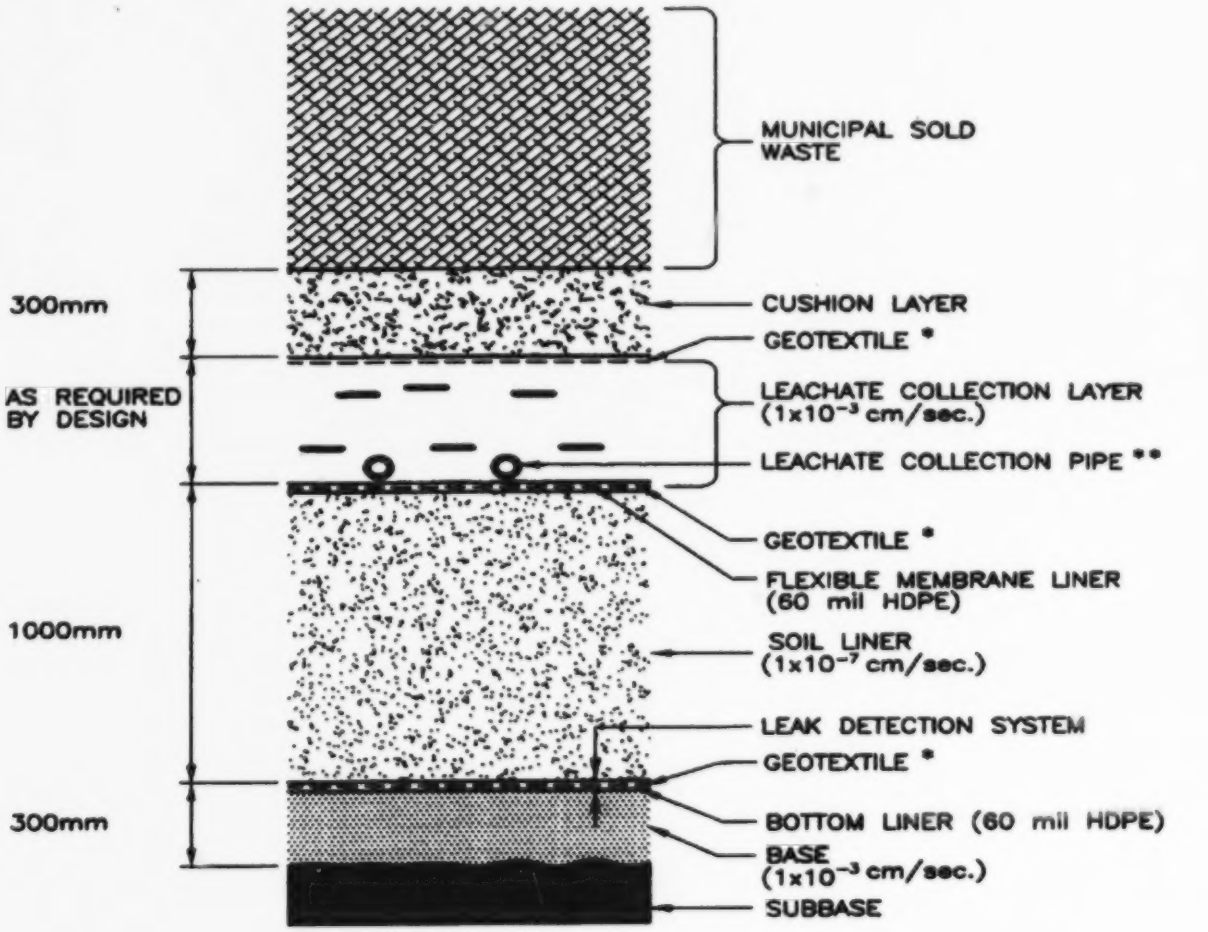
(c) Base

The base shall consist of material above the subbase with a minimum 300 mm thickness. There shall not be any bedrock or other rock outcroppings less than 300 mm below the surface of the base. The base material shall have a minimum hydraulic conductivity of at least 1×10^{-3} cm/sec.

(d) Bottom Liner and Leak Detection System

The Bottom Liner and Leak Detection System is to be installed such that it can provide for the detection and collection of a leak through the composite liner system. The seasonal high elevation of ground water elevation should not be higher than one meter below the lowest elevation of the leak detection system. The flexible membrane liner portion of the Bottom Liner and Leak Detection System must be manufactured of high density polyethylene (HDPE) of a minimum 60 mil thickness.

MUNICIPAL SOLID WASTE LANDFILL GUIDELINES



* GEOTEXTILES TO BE PLACED AS REQUIRED BY DESIGN.

** LEACHATE COLLECTION PIPE TO BE PLACED AS REQUIRED BY DESIGN.

FIGURE 1
TYPICAL LINER SYSTEM CROSS-SECTION

(e) Soil Liner Component

1. The soil liner component should have the following characteristics:

   (a) The soil liner should be protected during and after construction from damage due to frost, desiccation, over-hydration, differential movement and impact;

   (b) The soil liner shall be no less than 1000 mm in depth;

   (c) The soil liner should be placed in uniform, horizontal lifts of about 150 mm maximum loose thickness and constructed to ensure that the minimum hydraulic conductivity of the compacted soil is 1×10^{-7} cm/sec or less;

   (d) The proponent must specify the minimum hydraulic conductivity of the compacted soil, the compacted density of the soil required to obtain the design hydraulic conductivity and the optimum moisture content required to achieve the design hydraulic conductivity;

   (e) The soil may be amended, if required, with an admixture such as bentonite clay in order to achieve the required hydraulic permeability, however, the hydraulic conductivity must be uniform throughout the entire thickness of the soil.

2. There may be alternate technologies that may be employed in the design of the landfill liner system other than that described in items (a) to (d) above. If an Applicant wishes to use alternates, the Department may consider these methods provided:

   (a) Items (a) through (c) inclusive of Section **III. 3(e)1. Soil Liner Component** have been met; and

   (b) A detailed analysis has been presented to the Department and the Department is satisfied that the alternative technology is suitable for this application. The detailed analysis must demonstrate that the materials in question meet or exceed the performance of the soil component described in item (d) above. The analysis must include contaminant transport modelling (utilizing POLLUTE (©Rowe et al., 1994) or an approved equal) of the system and must include an analysis of the leachate compatibility with the liner components.

(f) Flexible Membrane Liner Component

The Flexible Membrane Liner (FML) component of the liner must be manufactured of a high density polyethylene (HDPE) of a minimum 60 mil thickness.

(g) Leachate Collection Layer

The Leachate Collection Layer is to provide a means of collecting all of the leachate without exceeding a leachate depth in this layer of 300 mm. The leachate collection system must be able to convey all of the leachate to a common point for treatment as required. The leachate collection layer should have a hydraulic conductivity of $1x10^{-3}$ cm/sec or greater. The collection system should be sloped such that it can adequately drain the leachate. The sloping should account for the possibility of settling occurring beneath the collection system network. Adequate protection should be placed above the leachate collection system to prevent clogging of this layer.

(h) Cushion Layer

A minimum 300 mm thickness cushion layer should be placed above the leachate collection layer. The cushion layer should be of structural fill material capable of separating the waste material from the leachate collection layer. Waste material, free of large or long objects which could cause stress to the liner, should be placed above the cushion collection layer.

4. Landfill Final Cover System

(a) General

1. The landfill final cover system should be placed above the waste material. The purpose of the cover system is to:

    - control the amount of surface water infiltration into the buried waste material;
    - limit erosion and sedimentation;
    - control the release of methane gas from the facility; and,
    - protect the underlying waste from exposure.

2. The landfill final cover system shall consist of the following components (see Figure 2 for a typical cross-section of a landfill final cover system):

    - grading pad;
    - low hydraulic conductivity layer;
    - drainage layer; and,
    - vegetative layer.

3. All components of the landfill final cover system should be designed to accommodate settling and consolidation of the waste material below such that ponding of water does not occur on the surface. A brief description of these components follows.

(b) Grading Pad

The grading pad is to be a minimum of 300 mm thick and should consist of structural fill material capable of supporting the material above. The grading pad must allow for the lateral movement of gases.

(c) Low Hydraulic Conductivity Layer

1. The low hydraulic conductivity layer should be designed to limit the surface water infiltration into the waste material. It should consist of either of the following components:

   (a) a Flexible Membrane Liner (FML) manufactured of a low density polyethylene (LDPE) of a minimum 40 mil thickness or equal; or,

   (b) a soil component consisting of a minimum of 750 mm constructed of soil with a hydraulic conductivity of 1×10^{-6} cm/sec or less.

2. The soil should be protected during and after construction from damage due to frost, desiccation, over-hydration, differential movement and impact. It should be constructed in layers such that it can achieve uniform compaction throughout its entire thickness.

3. The soil may be amended, if required, with an admixture such as bentonite clay in order to achieve the required hydraulic permeability, however, the hydraulic conductivity must be uniform throughout the entire thickness of the soil.

4. An alternative to the soil may be considered. Any alternate shall be subject to the same qualifying requirements for the application as per SECTION **III.3(e)1. Soil Liner Component**.

(d) Drainage Layer

The drainage layer should provide for the removal of infiltrated water from the vegetative layer and should protect the low hydraulic conductivity soil liner from damage due to desiccation, over-hydration, and impact.

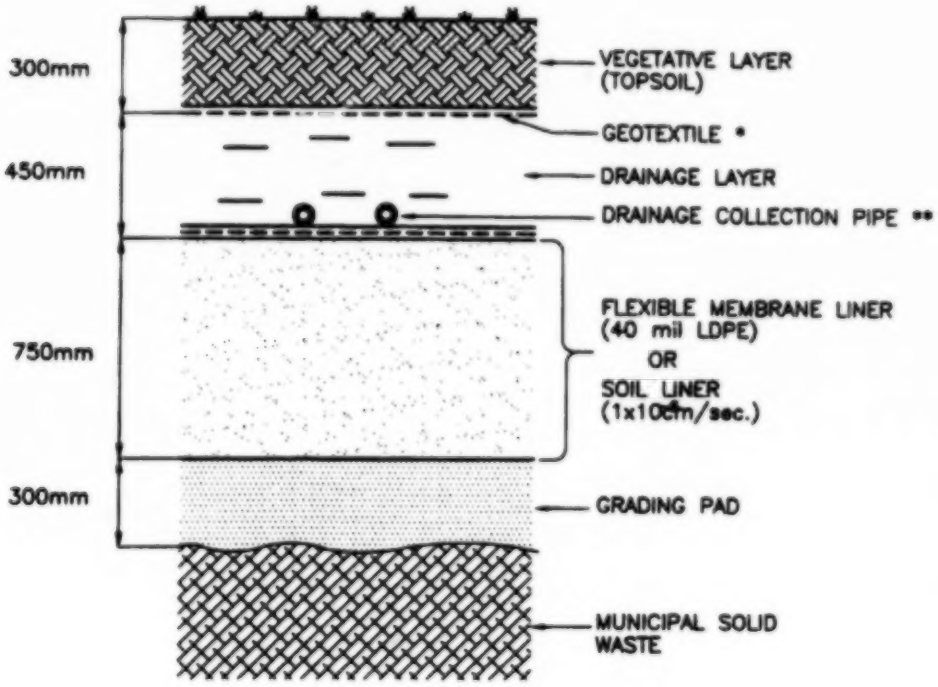
(e) Vegetative Layer

The vegetative layer should serve to stabilize the final cover system from the forces of wind and water erosion and to provide a low-maintenance surface. It should consist of a minimum 300 mm of topsoil with a vegetative surface.

5. Leachate Management System

(a) The leachate management system should consist of infrastructure and monitoring systems designed to monitor, control, treat and discharge treated leachate into the surrounding environment. The system should meet the minimum following requirements:

   1. It should have a leachate collection and removal network from the waste burial portion of the landfill which should be hydraulically separated from the facility's storm water system;
   2. It should function year round;
   3. It should function effectively during the lifespan of the landfill;
   4. It should have a means of monitoring all leachate flow. The systems must record both instantaneous and total flows; and,
   5. It should have adequate storage capacity.



* GEOTEXTILES TO BE PLACED AS REQUIRED BY DESIGN.

** DRAINAGE COLLECTION PIPE OR GEONET TO BE PLACED AS REQUIRED BY DESIGN.

FIGURE 2
TYPICAL FINAL COVER SYSTEM CROSS-SECTION

(b) All leachate which would be harmful if discharged into the surrounding environment shall be treated to remove contaminants. Leachate must be tested prior to discharge.

(c) The discharge standards for all liquid effluent will be related to the background water quality in the receiving water, identified current and projected uses of the receiving water and the Canadian Water Quality Guidelines for the protection of these defined water uses. Additionally, liquid effluents shall not be acutely lethal as determined by the suite of Biological Test Methods developed by Environment Canada for this purpose.

6. Landfill Gas Management System

Landfill gas production must be managed to control the discharge of potentially dangerous gases into the atmosphere. Venting and/or gas collection systems must be installed to control and monitor the gas production in the landfill. All new landfills must be assessed for the viability of energy recovery from the gas production. Landfill gas management systems will be evaluated on a case by case basis.

7. Surface Water Management

(a) Surface water management systems should be designed to do the following:

- divert surface and storm water from the disposal areas of the landfill
- control run-off discharge from the facility
- control erosion, sedimentation, siltation, and flooding
- minimize the generation of leachate

(b) All surface water management systems should be hydraulically separate from the facility's leachate management systems. (See Appendix 1 for an example of a typical surface and groundwater monitoring program.)

8. Groundwater Management

(a) Groundwater must be carefully managed to avoid contamination by leachate or surface water discharges. The seasonal high elevation of ground water must be maintained at a minimum of 1000 mm below the lowest point of the leak detection and bottom liner. Groundwater lowering systems must provide for positive drainage of the groundwater away from the landfill area.

(b) The distribution of groundwater monitoring wells should be landfill specific depending on the hydrogeological conditions of the landfill. The groundwater monitoring system should consist of a sufficient number of wells capable of providing locations to retrieve groundwater samples which would detect potential contaminant release pathways and which would provide background level samples. They are also to be used for the measurement of water levels, the determination of horizontal and vertical

gradients and the determination of flow directions and groundwater velocities. (See Appendix 1 for an example of a typical surface and groundwater monitoring program.)

(c) The groundwater monitoring system should consist of the following:

1. At least one groundwater monitoring well should be installed hydraulically above the gradient of the landfill and at least three monitoring wells should be installed hydraulically below the gradient direction;

2. The monitoring well system should include a sufficient number of multi-level well nests for measurement of vertical gradients;

3. Locations of the monitoring wells should be sufficiently close to the active disposal area to allow early detection of contamination and implementation of remedial measures; and,

4. The monitoring wells are to be retained throughout the lifespan of the facility.

9. Disposal Material Monitoring

All new landfills shall have systems in place to both monitor and control the material buried in the landfill. All new landfills should have an inspection station and weigh scales at the entrance to the landfill. The scales shall provide for accurate estimation of the material to be buried and/or separated. The monitoring station should also provide for inspection of the material to be buried before it is unloaded, where possible and where this is not possible, the Operations Manual for the site should include details of the method to be used to recover improperly discarded materials for removal from the landfill.

10. Separation Distances

(a) The distance between the active disposal area and the nearest residential, institutional, commercial or industrial building is recommended to be a minimum of 1000 m.

(b) The distance between the active disposal area and the nearest property boundary should be a minimum of 100 m.

(c) The distance between the active disposal area and the nearest bank top or high water mark of any surface water course or water body, including salt water, or to any off-site well should be a minimum of 100 m.

11. Quality Control/Assurance

(a) Quality control/assurance is defined as a planned system of inspections and activities that provide assurances that the design, manufacture and installation of systems and materials used in the landfill meet the purposes for which the systems and materials are intended.

(b) The Applicant shall provide a description of the quality control/assurance programs to be carried out on all aspects of the landfill system and materials. For specific items including, but not limited to, flexible membrane liners and low hydraulic conductivity soil components, quality control/assurance shall be carried out by an independent third party company to ensure that the materials are manufactured and installed as specified and in accordance with generally accepted practices and tolerances. (See Appendix 2 for an example of a typical quality control/assurance program.)

IV. LANDFILL OPERATION

1. General Requirements

Operation of the facility should incorporate, as a minimum, the following operational requirements:

(a) Cover should be placed at least once per day or more often as is required;
(b) The landfill should have constant supervision during the hours that the landfill is open;
(c) All loads must be inspected prior to unloading;
(d) The landfill shall accept only the materials identified in the approval;
(e) Litter must be controlled on the landfill;
(f) Exposed areas are to be stabilized to prevent erosion and sedimentation;
(g) Dust must be controlled as required;
(h) Vectors must be controlled as required; and,
(i) Appropriate signage must be placed at the entrance to the landfill which should indicate the name of the landfill, hours of operation, emergency contact, and the materials acceptable for disposal at the landfill.

2. Operation and Maintenance Manuals

(a) Operation and Maintenance Manuals shall be prepared which include the following:

1. Record drawings and specifications for the landfill;
2. A copy of the approval including terms and conditions for the landfill and any amendments to the approval;
3. A complete description of the operational requirements;
4. Monitoring logs including, but not limited to, monitoring well logs, leachate treatment records, gas management records and storm water management records;
5. Contingency plans;
6. Copies of all report forms that are to be used at the site; and,
7. Disposal records which include the generator, for single generator loads, and carrier for the materials.

(b) The Operation and Maintenance Manuals must remain on the landfill at all times and should be available for inspection during operating hours.

3. Contingency Plans

The Applicant must provide a contingency plan which identifies all reasonably foreseeable emergencies, such as fire, explosion, leachate leakage, spills and the like and describes appropriate remedial measures required to prevent damages to the landfill and the surroundings.

4. Reports and Records

Daily records of the operation must be completed and made available for inspection at all times. The Applicant must also report to the Department items described in the terms and conditions of the approval. The type and frequency of monitoring should be designed to reflect the size of the facility and the receiving environment. The following minimum items require reporting to the Department on an annual basis, with any exceedances of the approval to be reported within 24 hours, on forms provided by, or acceptable to, the Department:

1. Liquid effluent (leachate) monitoring both pre-treatment and post-treatment including:
    - (a) total flows, peak and average flows; and,
    - (b) leachate quality.
2. Gas production monitoring including total production, peak and average for landfills with landfill gas management systems.
3. Surface water monitoring and groundwater monitoring quality data.
4. Waste flow including:
    - (a) types of materials accepted at the landfill for the period;
    - (b) quantities of materials accepted at the landfill for the period;
    - (c) quantities of materials buried;
    - (d) quantities of materials separated for reuse and recycling; and
    - (e) quantities of materials composted, if composting at the facility exists.

V. LANDFILL CLOSURE

1. Closure Plan

The Applicant should include in the Application for approval, a preliminary closure plan for the landfill. The closure plan should include items such as the following:

(a) Anticipated date of closure;
(b) A description of waste that will remain as part of the closed facility;
(c) A description of all post-closure control and monitoring programs which will be carried out at the facility and the length of time they will be carried out;
(d) A description of any decommissioning of components of the facility; and
(e) A closure schedule of events.

2. Notification

At least 180 days prior to the planned closure of a landfill, the Applicant must notify the Department in writing of the intent to close the landfill. The notification should include a detailed description of the final closure plan.

3. Post-closure Requirements

The Applicant is responsible to ensure that all elements of the landfill closure plan are carried out for the lifespan of the facility.

Dated at Halifax, Nova Scotia, this 24th day of October, 1997.

original signed by:
Peter C. Underwood
Deputy Minister
Department of the Environment

Schedule "A"

Definitions:

(a) "Act" means the *Environment Act*, S.N.S. 1994-95, c.1;

(b) "active disposal area" means the areas used for disposal, stockpiles, storage, separation and processing.

(c) "Administrator" means a person appointed pursuant to Section 21 of the Act;

(d) "approval" means an approval pursuant to Section 31 (1) of the *Solid Waste-Resource Management Regulations*.

(e) "Department" means Nova Scotia Environment and Labour;

(f) "landfill" means a facility for the permanent disposal of municipal solid waste;

(g) "lifespan" means the period of time in which a facility will produce contaminants at levels which could have an adverse effect if discharged to the surrounding environment;

(h) "municipality" means a city, an incorporated town, a municipality of a county or district, or a regional municipality;

(I) "municipal solid waste" means garbage, refuse, sludge, rubbish, tailings, debris, litter and other discarded materials resulting from residential, commercial, institutional and industrial activities which are commonly accepted at a municipal solid waste management facility, but excludes industrial waste from an industrial activity regulated by an approval issued under the Act.

APPENDIX 1

TYPICAL SURFACE AND GROUNDWATER MONITORING PROGRAM

1.0 SITE ASSESSMENT AND DESIGN

1.1 Hydrogeologic Assessment

Prior to the establishment or expansion of a site, a report shall be prepared by the owner containing plans, specifications, and descriptions of the hydrogeologic conditions of the site, adjacent and nearby properties, and the regional area in which the site is located, including at a minimum, the following;

.1 a general description of the regional geologic and hydrogeologic conditions occurring within 5 km of the site. This description should identify any unstable soils or bedrock, indicate the location and nature of any boundaries to groundwater movement, and characterize the significance of groundwater resources and the use made of these resources;

.2 a description of local hydrogeologic conditions occurring at the site, and adjacent and other properties within 500 m of the site, and the description shall indicate how local conditions relate to regional conditions;

.3 a detailed hydrogeologic investigation of the site which establishes soil, rock, and groundwater conditions;

.4 an interpretation of the results of the detailed hydrogeologic investigation of the site, including plans, specifications, and descriptions:

.5 an assessment of the suitability of the site for water disposal purposes considering the regional, local, and site specific hydrogeologic conditions, the design of the site, and the contingency plans for the control of leachate and landfill gas.

1.2 Surface Water Assessment

Prior to the establishment or expansion of a site, a report shall be prepared by the owner containing plans, specifications, and descriptions of the surface water conditions of the site, adjacent and nearby properties, and the regional area in which the site is located, including, at a minimum, the following:

.1 a general description of the surface water features occurring within 5 km of the site that is based on the contributing/receiving drainage area, catchment, subwatershed or watershed that is sufficiently large to assess the range and extent of potential effects. This description will include, but not be limited to, flood plains, natural watercourses, drainage paths and boundaries, streamflows, surface water quality, and sources of water

supply;

.2 a description of the local surface water features occurring at the site, and adjacent and other properties within 500 m of the site, and the description shall include how local feature relate to regional features;

.3 a detailed surface water investigation of the site to assess water quality, quantity, and habitat conditions of the surface water features identified on site;

.4 an interpretation of the results of the detailed surface water investigation of the site, including plans, specifications, and descriptions;

.5 an assessment of the suitability of the site for waste disposal purposes considering the regional, local, and site specific surface water conditions, the design of the site, and the contingency plan for the control of leachate.

2.0 OPERATION AND MONITORING

2.1 Groundwater Monitoring

A program for monitoring groundwater quality and quantity shall be carried out by the owner and shall include, at a minimum, the following:

.1 representative samples of groundwater within the site shall be:

a) obtained annually from groundwater monitoring facilities and be analyzed for the parameters listed in column 1 of Schedule 1; and

b) obtained quarterly from groundwater monitoring facilities and be analyzed for the parameters listed in column 2 of Schedule 1;

.2 where requested by property owners or occupants, representative samples of groundwater shall be obtained from domestic wells located within 500 m of the site at a frequency of 1 sample per well per year and these groundwater samples shall be analyzed for the parameters listed in column 2 of Schedule 1;

.3 the results of analysis of a water sample collected under Subsection 2.1.2 shall be provided to the Department and the owner or occupant of the property with the domestic well from which the sample was obtained, within 60 days of obtaining the sample;

.4 the results of analysis of all water samples collected in the groundwater monitoring program, together with an assessment of these results shall be provided to the Department in an annual report, and where the assessment indicates a significant increase in contaminant concentrations, within 60 days of obtaining the sample and 5 days of making the assessment;

.5 the parameters to be monitored may be amended where the owner prepares a report showing alternative parameters should be monitored, based on the type of waste to be deposited at the site.

2.2 Surface Water Monitoring

A program for monitoring surface water quality, quantity, and biological features shall be carried out by the owner and shall include, at a minimum, the following:

.1 representative samples of surface water being discharged from the site and of any waterbody, including upstream control locations, which may be affected by leachate, stormwater runoff, or sediment from the site , shall be:

a) obtained semi-annually, and be analyzed for the parameters listed in column 3 of Schedule 1 and for other parameters of concern identified in the surface water assessment;

b) obtained quarterly and be analyzed for the parameters listed in column 4 of Schedule 1;

.2 annual monitoring of biological features to assess the composition and any changes to the benthic community present in any waterbody, located downstream of storm water discharges, that may be affected by leachate, stormwater runoff, or sediment from the site;

.3 the results and assessment of the results of the surface water monitoring shall be provided to the Department in an annual report, and where the assessment indicates an increase in contaminant concentrations exceeding the natural variability exhibited by baseline and operational monitoring data, within 60 days of obtaining the sample and 5 days of making the assessment;

.4 the parameter to be monitored may be amended where the owner prepares a report showing alternative parameters should be monitored, based on the type of waste to be deposited at the site.

Schedule 1
Groundwater, Leachate and Surface Water Monitoring Parameters

	Parameter			
Parameter Group	Column 1	Column 2	Column 3	Column 4
	Comprehensive List for Groundwater and Leachate	Indicator List for Groundwater and Leachate	Comprehensive List for Surface Water	Indicator List for Surface Water
Inorganics				
	Alkalinity	Alkalinity	Alkalinity	Alkalinity
	Ammonia		Ammonia	Ammonia
	Arsenic		Arsenic	
	Barium		Barium	
	Boron		Boron	
	Cadmium	Cadmium	Cadmium	
	Calcium	Calcium		
	Chloride	Chloride	Chloride	Chloride
	Chromium		Chromium	
	Conductivity	Conductivity	Conductivity	Conductivity
	Copper		Copper	
	Iron	Iron	Iron	
	Lead	Lead	Lead	
	Magnesium	Magnesium		
	Manganese			
	Mercury		Mercury	
	Nitrate	Nitrate	Nitrate	Nitrate

Parameter				
Parameter Group	Column 1	Column 2	Column 3	Column 4
	Comprehensive List for Groundwater and Leachate	Indicator List for Groundwater and Leachate	Comprehensive List for Surface Water	Indicator List for Surface Water
	Nitrite		Nitrite	Nitrite
	Total Kjeldahl Nitrogen		Total Kjeldahl Nitrogen	Total Kjeldahl Nitrogen
	pH	pH	pH	pH
	Total Phosphorus		Total Phosphorus	Total Phosphorus
	Potassium	Potassium		
	Sodium	Sodium		
	Suspended Solids	Suspended Solids	Suspended Solids	Suspended Solids
	Total Dissolved Solids	Total Dissolved Solids	Total Dissolved Solids	Total Dissolved Solids
	Sulphate	Sulphate	Sulphate	Sulphate
	Zinc		Zinc	
Volatile Organics				
	Benzene			
	1, 4 Dichlorobenzene			
	Dichloromethane		Dichloromethane	
	Toluene		Toluene	
	Vinyl Chloride			

Parameter				
Parameter Group	Column 1	Column 2	Column 3	Column 4
	Comprehensive List for Groundwater and Leachate	Indicator List for Groundwater and Leachate	Comprehensive List for Surface Water	Indicator List for Surface Water
Other Organics				
			Biochemical Oxygen Demand (BOD_5)	Biochemical Oxygen Demand ($B0D_5$)
	Chemical Oxygen Demand	Chemical Oxygen Demand	Chemical Oxygen Demand	Chemical Oxygen Demand
	Dissolved Organic Carbon	Dissolved Organic Carbon	Total Organic Carbon	
	Phenol		Phenol	Phenol
Field Parameters				
			Temperature	Temperature
	pH	pH	pH	pH
	Conductivity	Conductivity	Conductivity	Conductivity
			Dissolved Oxygen	Dissolved Oxygen
			Flow	Flow

APPENDIX 2

TYPICAL QUALITY CONTROL/ASSURANCE PROGRAM

1.0 PURPOSE

1.1 Quality Control

.1 For the purpose of this specification, quality control shall be defined as a planned system of inspection and tests to directly monitor and control the quality of the work.

.2 The Applicant shall submit a quality control, inspection and test program for all landfill components.

.3 The Applicant shall employ a quality control inspector (Inspector) who may be the same person as the installation supervisor.

1.2 Quality Assurance

.1 For the purpose of this specification, quality assurance is defined as a planned system of activities carried out by the Applicant or his Representative that provides assurance that the landfill components were manufactured and installed as specified.

.2 The quality assurance program shall include tests similar to those carried out for quality control.

2.0 GEOMEMBRANE

2.1 General

Geomembranes shall be tested for both manufacture and installation. Both destructive and non-destructive tests shall be used.

2.2 Geomembrane Testing

.1 A minimum of one complete set of quality control tests on geomembrane rolls shall be performed at the frequencies given in Table 1 to verify that all other specified parameters are in compliance with the material specifications.

.2 Test samples which fail to meet strength and environmental specifications

shall result in rejection of applicable rolls. Further testing on geomembrane manufactured from the same resin batch shall be conducted to determine acceptability.

.3 A quality assurance consultant shall confirm that required quality control has been done and shall certify the quality of the geomembrane, prior to delivering. A quality control certificate is required for each batch of resin and each production shift. The certificate shall include:

Product Identification
Roll Numbers
Sampling Procedures
Test Methods
Test Results (including Environmental Stress Cracking or single-point Notched and Constant Tensile Load Time to Failure test data)
Signature of Responsible Party

The consultant may also request that all production line records be submitted for review.

.4 The consultant shall have authority to visit the manufacturing facility at any time to witness production and quality control testing, examine production records and take independent samples.

2.3 Non-Destructive Testing

.1 Test Seams (Start-up) - Test seams shall be made to verify that adequate conditions exist for field seaming to proceed. Each seaming apparatus shall produce a test seam at the beginning of each shift. In addition, if a seaming operation has been suspended for more than four hours, or after every 5 hours or if a breakdown of the seaming equipment occurs, a test seam shall be produced prior to resumption of seaming operations.

Test seams shall be made in the field on pieces of the approved geomembrane. Each test seam shall be at least 1.5 m long by 300 millimetres wide for extrusion and 3 m long by 300 millimetres wide for fusion, with sufficient overlap for peel testing in the field tensiometer.

Two samples 25 millimetres wide shall be taken from each end of the test seam using an approved template. The samples shall be tested in the field tensiometer, one from each and in peel and shear respectively. Samples tested in peel shall not fail in the seam. All test samples shall exhibit film tear bond and strength as defined under seam properties, Table 1.

Table 1
Geomembrane

Material Property	Minimum Average Roll Values (Metric)	
Nominal Thickness		1.5 mm (60mils)
	Units	Value
Thickness, ASTM D751, NSF Mod., Nominal	mm	1.50
Indent Lowest Individual Reading	mm	1.37
Density, ASTM D1505	g/cm^3	0.940
Melt Flow Index, ASTM D1238 Cond. E. Max	g/10 min.	1.0
Carbon Black Content, ASTM D1603	percent	2.0 - 3.0
Carbon Black Dispersion, ASTM D3015	rating	A2
Minimum Tensile Properties, ASTM D638 Stress at Yield	N/cm	231
Stress at Break	N/cm	399
Stress at Yield nominal gage of 1.30" per NSF Mod.	percent	13
Stress at Break nominal gage of 2.5" per NSF Mod.	percent	560
Tear Resistance, ASTM D1004	N/cm N	1230 200
Puncture Resistance, FTMS 101, 2065	N/cm N	2280 347
ESCR, ASTM D1693, NSF Mod., Pass	hours	1500
Dimensial Stability, ASTM D1204, NSF Mod., Max.	percent	2.0
Low Temperature Brittleness	°C	-60
Single-Point Notched Constant Tensile Load time to Failure	(hr)	200
Field Seam Properties 1. Shear Strength 2. Peel Strength	 N/cm N/cm	 212 FTB and 139
1. Film Tear Bond (FTB) is defined as failure of one of the sheets by tearing, instead of separating from the welded seam - that test specimen shall no fail by more than 10% into the seam. For double hot wedge fusion welded seam, both inside and outside tracks shall be tested.		

If the seam fails to pass, the seaming apparatus shall not be used for field seaming until any deficiencies have been corrected. This shall be verified by the production and successful testing of two consecutive test seams.

.2 Vacuum Testing - All extrusion welded seams and "T" seams shall be evaluated using vacuum box testing.

A sudsy soap solution shall be applied to the test section and the vacuum box placed over the section. The vacuum box shall maintain at least .2 bar vacuum during the test. Once a tight seal has been established, the test section shall be viably examined for a period of not less than 10 seconds to determine whether bubbling of the soapy solution at the seam is occurring. The vacuum box is then moved and the process is repeated on the next adjacent section. A minimum of 100 millimetres overlap shall be provided between all test sections.

All locations where bubbling of the sudsy solution is observed shall be clearly marked for repairs with a high visibility marker and recorded by number on field test reports. Any failed portion of seam shall be repaired and retested.

.3 Air Pressure Testing - Double wedge welded seams shall be sealed off at both ends. If the end of a seam will be an integral part of the geomembrane, the sealing shall be done in such a way that it does not harm the function of the geomembrane. The pressure feed device shall be inserted into the air channel at one end of the seam and pressurized to 1.5 - 2.0 bars. The feed valve shall be closed and the pressure sustained for a period of not less than 3 minutes. The pressure shall then be released by slitting the air channel at the opposite end of the seam. The Inspector shall observe the drop in pressure on the manometer to verify the continuity of the air channel.

If a pressure loss of greater than .2 bar is observed or if the required pressure cannot be reached, then the seam shall be rejected, and shall be either reconstructed in its entirety or the leak located and patched. The entire seam shall then be retested according to the procedure outlined above.

.4 All seams shall be non-destructively tested by the Installer over their full length to verify the integrity of the seam. Non-destructive testing shall be performed concurrently with field seaming. All non-destructive testing shall be observed and documented by the Inspector.

.5 Seams failing a test shall be repaired and retested.

.6 Cap seams which cannot be subjected to a non-destructive test using geomembrane of the same batch under the supervision of the inspector. Test the cap seams. Alternatively, remove the seam and adjacent geomembrane panel, replace and test.

2.4 Destructive Testing

.1 Destructive testing of field seams shall be performed at selected locations in order to verify seaming properties. All sampling and testing shall be done concurrently with field seaming so that verification of field seam properties is made as the work progresses and corrective action implemented, if necessary.

.2 Test samples shall be taken at an average frequency of one test location per 150 meters of seam. Sample locations shall be determined by the Inspector taking into consideration the difficulty of subsequent repair and testing.

.3 Samples shall be cut under the direction of the Inspector. Each sample shall be indelibly numbered and identified. Each sample shall be identified with the sample number, seam number, panel number, date, name of welding technician, and welding equipment number.

.4 The Inspector may increase the amount of destructive testing based on the results of previous testing. Additional samples may also be required when the Inspector has reason to suspect the presence of excess crystallinity, contamination, faulty seaming equipment or any other reason affecting seam quality.

.5 The test sample shall measure approximately 300 millimetres wide by 1.0 metre long with seam centred lengthwise along the sample.

.6 25 mm wide sample strips shall be cut from the sample using an approved die, and tested by an on-site tensiometer. Two 25 mm wide samples shall be taken from each end for shear and peel testing. The seam shall not fail either test as specified in Section 2.3.

.7 The remaining sample shall be tested in an independent tensiometer to qualify seam strength properties and FTB according to the procedures outlined in this section.

The Inspector shall cut ten (10) 25 mm wide replicate specimens from his sample and shall test 5 specimens for seam shear strength and 5 for peel strength. To be acceptable, 5 out of the 5 replicate specimens must pass for each mode of testing. All specimens must fail in Film Tear Bond (FTB); any specimen that fails through the weld, or by adhesion at the weld-sheet interface, is a non-film Tear Bond break and shall be considered a failure.

.8 The test method and procedures to be used by the Inspector shall employ

a grip separation rate of 50 mm/min for peel and shear.

.9 The area from which the destructive test sample was take shall be repaired without delay and shall be non-destructively tested by vacuum box as described in Section 2.3.2.

2.5 Inspection and Acceptance

.1 As the work progresses, the Inspector shall document all locations requiring repair work and shall verify and document that all repairs have been successfully made. No work on the liner shall be allowed if the Inspector is not present. This is to include start-up tests, general seaming and patching, and any work at penetrations or structures.

.2 Seams are only considered to be accepted after they have passed the specified non-destructive and destructive tests, and the equipment used to produce the seams have passed the required start-up tests. If a seam fails the above criteria, the seam must be reconstructed.

.3 A double hot wedge fusion seam shall be considered acceptable only when both outside and inside track welds are destructively tested and meet the specification criteria.

.4 If a seam fails the destructive test, the seam may be reconstructed between the point of failure and any previously accepted test.

.5 In lieu of .4 above, the Installer may trace the extent of unacceptable seam. Take 25 mm samples at minimum 3 metre distance on each side of failed section. Test in both shear and peel. If one or both tests fail, continue along seam at minimum 3 metre increments. Continue until tests indicate pass results. Then take large samples for field laboratory tensimeter testing. If field laboratory tests pass, make repairs - if fail, continue.

.6 Reconstruction or repair of failed seam lengths shall be either by capping of the failed seam (extrusion or fusion weld) or, in the case of a double fusion weld, by extrusion fillet welding the overlap to the bottom sheet. Cutting off the overlap and topping the failed fusion weld with extrudate will not be permitted.

.7 If the overlap of the outside (i.e. visible) weld is less than 30 mm extrusion welding of the overlap to the bottom sheet in the failed section will not be permitted.

.8 Continuity of all reconstructed seams to be subject to non-destructive

testing. If reconstructed length exceeds 50 metres, sample shall be taken for laboratory destructive testing.

.9 The entire geomembrane surface shall be examined by the Inspector to confirm that it is free of any defects, blisters, undispersed raw materials, or contamination by foreign matter. The geomembrane surface shall be cleaned, if required, so that it is free of dust, mud, debris or any other material which may inhibit a thorough examination of the surface. Any suspect areas shall be clearly marked by the Inspector and non-destructively tested according to the appropriate specified testing procedure.

.10 Overburden shall not be applied to any portion of the liner system until that portion system is inspected and has been approved.

.11 Gouges or scratches associated with grinding or from other sources whose depth is in excess of 10% of the geomembrane thickness shall be classified as defects and will require appropriate repairs in accordance with these specifications.

.12 Small tears, wrinkles or pinholes to be repaired by seaming or patching. Other areas to be patched or capped.

.13 Patches shall be round or oval, of the same material and thickness, and shall extend a minimum of 150 mm beyond the damaged or faulty area in all directions.

.14 Geomembrane surfaces to be patched shall be abraded, in accordance with these Specifications. Surfaces must be clean and dry.

.15 Use approved extrusion welding equipment.

.16 All repairs to be non-destructively tested.

.17 Cut and repair any large wrinkles or "fishmouths" identified by the Inspector.

3.0 SOIL LINER

3.1 Soil Liner Quality Control

Quality control of low permeability fill material and placement shall be based on the following minimum procedures and criteria:

.1 Prior to constructing the soil liner, a test section shall be constructed in two lifts to the specified thickness, consisting of not less than three panels 3 m wide and 10 m long.

.2 Mixing methods shall be modified as necessary to achieve specified coefficient of permeability.

.3 Placement and compaction methods shall be modified as necessary to achieve specified coefficient of permeability.

.4 Samples and measurements of test section shall be taken. Physical parameters to be tested in the laboratory include grain size, moisture content, Atterberg Limits, moisture density relationship and hydraulic conductivity. Compacted in-situ density (by Nuclear Method ASTM D2922) and permeability by air entry infiltrometer shall be measured.

.5 The method of construction, verified by the Applicant shall then be submitted to Nova Scotia Environment and Labour. Once submitted, no deviation from the method of construction will be allowed by the contractor unless written approval is obtained from the Department.

.6 The Installer shall employ a certified geotechnical company with laboratory testing capabilities that can supply the qualified personnel and equipment necessary to perform the required tests.

.7 The geotechnical company shall perform all required tests on the soil liner material at the mixing/stockpile area. The results of these tests shall be approved prior to the material being used for liner construction.

.8 The geotechnical company shall perform all tests on the liner subgrade. The results of these tests shall be available for inspection as required.

.9 The geotechnical company shall perform all required tests on the liner material while it is being placed, and after it is complete, as defined in this specification. The results of these test shall be submitted for approval immediately upon completion of the Test.

.10 The geotechnical company shall certify that all specified requirements are

met.

3.2 Soil Liner Quality Assurance

.1 Quality Assurance of soil liner material and placement shall be based on the following minimum procedures and criteria:

.1 An independent Inspector shall perform all required tests on the soil liner material at the stockpile area. The results of these tests shall be submitted for approval prior to the material being used for liner construction.

.2 The Inspector shall perform all required tests on the soil liner material while it is being placed, and after it is complete. The results of these tests shall be submitted for approval immediately upon completion of the tests.

.3 The average results of any ten consecutive density tests shall be equal to or greater than the specified density.

.4 Results of not more than two in any ten consecutive density tests may be less than the specified density.

.5 Results of any ten consecutive moisture content tests shall be within the specified moisture content limits.

.6 Results of not more than two in any ten consecutive moisture content tests may lie outside the specified content limits.

.7 Permeability evaluated from results of tests shall be equal to or less than the specified permeability.

.8 Average of results of any ten consecutive grain size tests shall be within the specified limits for grain size.

.9 The testing shall include the items identified in Table 2 as a minimum:

Table 2
Soil Liner Testing

Item	Testing	Minimum Frequency
Soil Prior to Placement	Moisture Content	750 m^3
	Moisture-density curve	1 test/4000 m^3
	Grain Size	1 test/750 m^3
	Atterberg Limits (liquid limit and plasticity index)	1 test/4000 m^3
	Lab permeability (remolded samples)	1 test/7500 m^3
In Place Liner	Density	Every 200 m^2 of exposed lift surfaces
	Moisture Content	100 m^3
	Atterberg Limits (liquid limit and plasticity index)	2 tests/hectare/lift
	Grain size (to the 2-micron particle size)	2 tests/hectare/lift
	Moisture-density curve	1,500 m^3 or a minimum of 1 every 3 days of placement
	Laboratory permeability of undisturbed soil sample	2 tests/hectare/lift - air entry apparatus
	In-situ permeability	5 tests/hectare/lift - undisturbed Shelby sample

.10 Any portions of the completed liner which do not achieve compacted dry density and moisture contents in the range specified shall be replaced.

.2 Method of testing of the soil liner shall be as follows:

.1 The maximum density of low permeability fill and the optimum water content for compaction will be determined in accordance with ASTM D698, Method D.

.2 Bulk density will be determined in the field in accordance with ASTM D2922 or with ASTM D1556, whichever is most suitable, to obtain a representative density of the fill tested.

.3 Particle size analysis of the soil will be performed in accordance

with ASTM D422.

.4 Samples for hydraulic conductivity testing of the compacted fill shall be collected in thin walled Shelby tubes from the compacted liner and tested in the laboratory. Confining pressure during the permeability testing will be equal to the applicable surcharge load.